Summary Report

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Title: Martian Atmospheric Circulation and Climate
NASA/Goddard Grant No. NAG5-9601
Period of Performance: May 1, 2000 – April 30, 2003

Introduction

This proposal is focused on using MGS data and numerical models to address issues of atmospheric mixing of volatiles and aerosols, on defining the mean state of the atmosphere and the degree of variability, and on the processes which exchange volatiles and aerosols between the surface and atmosphere. Specifically, five areas of research were defined:

- *In the first*, we proposed to use TES data to examine the general circulation of the atmosphere both through retrieval of the residual circulation, and by comparison of the TES data with a Mars GCM.
- *In the second*, we proposed to look at synoptic and mesoscale atmospheric mixing processes (baroclinic storms, *etc.*) by combining TES and MOC Wide Angle data, and by employing a Mars Mesoscale Model.
- *In the third section*, we proposed to examine the record of the Martian atmospheric state provided by MGS, Viking, and Mariner 9 - as well as published ground-based observations – in order to assess the nature of interannual variability.
- *In the forth section*, we proposed to compare numerical models of the Martian water and dust cycles with TES and MOC data, specifically looking at water ice cloud distributions, dust distribution, *etc.*
- *In the fifth section,* we propose to use the mesoscale model to study the Mars Pathfinder Lander data.

This work has now concluded its final of three years.

Work by Task:

1. Progress in Year 1 included code development and validation. The code consists of two parts: that which generates radiative heating rates from knowledge of the solar incident radiation field and the observed (retrieved) TES air temperature cross sections, and that which inverts the heating rate field to derive the circulation. The former code is based on the heating rate algorithm used in the GFDL Mars GCM. The latter is based on that developed by Santee and Crisp [1993] to examine Mariner 9 data. This code has been used to examine pre-mapping data (*i.e.* with temperature retrievals from nadir viewing only) but resulted in poor retrieved circulations, likely due to local time biases in the sampling. Retrievals with combined nadir-limb observations from the mapping mission appear more satisfactory. However, significant issues remain with the retrieved circulation. We are exploring whether these problems are associated with errors in the temperature/heating rate schemes or if application of diurnal mean circulation diagnostics have significant meaning in an atmosphere with such a strong diurnal thermal tide. This work was not completed during the proposal period.

2. We reduced and mapped MOC WA color images and used them in combination with simultaneous TES observations. We conducted modeling of two types of "weather" systems: polar cap edge dust storms, and frontal storm systems; using both the Mars mesoscale model (MM5) and Mars GCM. In the former case, this has led to a paper published in JGR (Toigo *et al.*, 2002). The latter is published in GRL (Wang *et al.*, 2003).

3. Inter-comparison of the extended spacecraft record of the Martian climate requires a truly comparable data set. The dangers of misinterpreting retrieval and instrumental differences as real differences are great - there exist precedents that demonstrate this danger (see e.g. Richardson [1998]). In this vein, we have carefully converted the TES spectral data into a multi-band radiometer data set using the infrared-bands defined by the Viking IRTM channel spectral response functions. We have used the Martin [1986] and Martin and Richardson [1993] scheme to retrieve 9-μm dust opacities for the entire PDS-released TES record, including some augmentations to the original code (such as the inclusion of measured IRTM-band surface emissivities [Christensen, 1998], MOLA-based topographic correction, and specifiable vertical distributions of dust). We have further converted the code to retrieve 11-μm ice cloud optical depths (based on the difference in extinction between 11- and 20-μm, again using the measured surface emissivities). Both schemes have been carefully tested against MOC WA images and the official TES-team retrievals, favorably. Broad comparisons between the TES and IRTM data sets have been conducted for air temperature (using the 15-μm channel), and 9-μm and 11-μm opacities. This work is in the last stages of galley-proofing before publication at JGR (Liu *et al.*, 2003).

4. We have completed comparisons of water ice clouds observed by MOC and TES and predicted by the GCM. Good agreement is found for the extent, location, and timing of the northern summer tropical cloud belt. The agreement is found to be sensitive to both atmospheric temperatures and ice particle size. This work is published at JGR (Richardson and Wilson, 2002). Comparison between the model and TES-observed air temperatures and dust opacity also produce interesting results, including the finding that southern polar cap dust enhancements appear to occur in each observed year of IRTM and TES. The mesoscale model predicts surface stresses sufficient to lift dust by the large-scale winds in this location and season (the only such occurrence for any numerical model of the Martian atmosphere). Our GCM modeling suggests that dust lofted in this region at this season should not spread to other latitudes.

5. The mesoscale model developed as part of this proposal has been a functioning part of our modeling suite for about a year now. We have completed comparisons of the Mars MM5 with the GCM at similar resolution and with all the available surface meteorological station data (MPF, VL1, VL2). We find excellent agreement with the GCM and relatively good agreement with surface observations. The results of this work have been published in JGR (Toigo and Richardson, 2002).

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